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Skinfolds and Coronary Heart Disease Risk Factors are More Strongly Associated with BMI Than with the Body Adiposity Index

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Abstract

Objective—A recent, cross-sectional analysis of adults found that the hip circumference divided by height$^{1.5}$ minus 18 (the body adiposity index, BAI) was strongly correlated ($r = 0.79$) with percent body fat determined by dual energy X-ray absorptiometry. The BAI was proposed as a more accurate index of body fatness than BMI. We examined whether BAI was more strongly related, than was BMI and waist circumference, to skinfold thicknesses and levels of various risk factors for coronary heart disease.

Design and Methods—Cross-sectional analyses of adults ($n = 14{,}263$ for skinfold thickness; n=6291 for fasting lipid levels) in the National Health and Nutrition Examination Survey (NHANES) III, 1988–1994.

Results—As compared with BMI and waist circumference, we found that BAI was less strongly associated with the skinfold sum and with risk factor levels. For example, correlations with the skinfold sum were $r = 0.79$ (BMI) vs. $r = 0.70$ (BAI) among men, and $r = 0.86$ (BMI) vs. $r = 0.79$ (BAI) among women; $p < 0.001$ for the difference between each pair of correlations. An overall index of the 7 risk factors was also more strongly associated with BMI and waist circumference than BAI in analyses stratified by sex, race-ethnicity and age. Multivariable analyses indicated that if BMI was known, BAI provided little additional information on risk factor levels.

Conclusions—Based on the observed associations with risk factor levels and skinfold thicknesses, we conclude that BAI is unlikely to be a better index of adiposity than BMI.

Introduction

Although the limitations of the body mass index (BMI) are well known, this index remains widely used as a simple indicator of adiposity and 30 kg m^{-2} is the cut-point for obesity among adults. An alternative index, the body adiposity index, was recently proposed (1):

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$$\text{Body Adiposity Index (BAI)} = \frac{\text{Hip circumference (cm)}}{\text{Height (m)}^{1.5}} - 18$$

Among 1,733 adults, it was found that percent body fat (calculated from dual-energy X-ray absorptiometry (DXA)) was moderately correlated with hip circumference ($r = 0.60$) and height ($r = -0.52$), and the ratio of these two measures was suggested as an index of body fatness. Raising height to the 1.5 power was found to maximize the correlation between this ratio and percent body fat ($r = 0.79$); 18 was the estimated intercept of a regression model predicting percent body fat. Furthermore, these investigators found that BAI predicted the percent body fat of black adults in a second sample ($r = 0.85$), and it was concluded that this index provides a direct estimate of percent body fat without the need for further adjustment (1). Other results (2,3), however, have not confirmed that BAI is more strongly associated with DXA-determined percent body fat than is BMI.

The use of hip circumference as the numerator of an adiposity index is surprising as persons with larger hip circumferences, relative to BMI, are at lower risk for coronary heart disease (CHD) and total mortality (4). The use of hip circumference in the waist-to-hip ratio (WHR) (5,6), a simple index of abdominal obesity, also suggests that at similar levels of waist circumference, persons with a larger hip circumference may be at lower risk for type 2 diabetes (7) and CHD (6,8).

The purpose of the current study is to compare the magnitude of the associations of BAI and BMI to the sum of four skinfold thicknesses, which is used as a simple index of body fatness, and levels of CHD risk factors (lipids, fasting glucose, fasting insulin, and blood pressure) among adults in the 1988–1994 National Health and Nutrition Examination Survey (NHANES III). Although this survey does not have a direct measure of body fatness, it is the most recent national survey that measured hip circumference. If BAI were a better index of adiposity than BMI, it would be expected that BAI would be more strongly correlated with skinfold thicknesses and metabolic risk factors than would BMI.

Methods

Design and analytic sample

The current analysis is based on data from NHANES III, 1988–1994 (9). NHANES is a series of cross-sectional, nationally representative surveys conducted by the National Center for Health Statistics (NCHS) at the Centers for Disease Control and Prevention (CDC). The procedures for selecting the sample and conducting the interviews, examinations and laboratory analyses for NHANES III have been published (10–12). In NHANES III, data on self-reported race-ethnicity was categorized as non-Hispanic white, non-Hispanic black, Mexican-American, and "other." Because levels of low-density lipoprotein cholesterol (LDL-C) were calculated only for persons who participated in the morning examination, while body size measures were obtained irrespective of the time of day, two samples are used in the current analyses.

In the first sample for the analysis of the body size measures, we used the sum of four skinfold thicknesses (subscapular, triceps, suprailiac, and thigh) as a simple indicator of adiposity (13,14). Of the 16,742 men and nonpregnant women who were examined in NHANES III, 3,474 were missing data for at least one of these four measures. However, about 40% of these subjects had missing data because a skinfold thickness exceeded the capacity of the caliper (15). We recoded these "exceeded capacity" missing values to 50 mm, a value that was 1 mm higher than the largest recorded skin-fold thickness. Because these missing skinfold values were strongly associated with obesity, simply excluding them from the analyses could bias the observed associations. In our analyses of the relation of BAI to the skinfold sum, we excluded an additional 55 subjects who were missing data for BMI, BAI or waist circumference. This resulted in an analytic sample of 14,263 adults.

The second sample focused on the analysis of risk factor levels, and was restricted to subjects who participated in the morning examination (n = 8,158). This morning sample was chosen to be representative of all persons in NHANES III (16), and subjects were asked to fast overnight. LDL-C levels were calculated using the Friedewald equation (17) for the 6784 persons in the morning session who had had fasted from 8 to 24 h and who had a triglyceride level ≤400 mg dL^{-1}. Only a small proportion (7%) of subjects in the morning examination had fasted for <8 h, but most (69%) of those examined in the afternoon and evening had not fasted. Previous analyses of LDL-C and triglyceride levels in NHANES have been based on the morning, fasting sample (18).

Of the 6,784 subjects who had recorded values of LDL-C, we excluded 390 subjects who were missing data on either levels of glucose (n = 106), insulin (n = 40), systolic blood pressure (SBP) or diastolic blood pressure (DBP) (n = 7), BMI (n = 14), BAI (n = 230), or waist circumference (n = 236). These exclusions resulted in an analytic sample of 6,291 subjects who had complete data for BMI, BAI, waist circumference, and the seven CHD risk factors. Mean levels of various characteristics (e.g., skinfold thicknesses, BMI, BAI, waist circumference, SBP, DBP, high-density lipoprotein [HDL] cholesterol) were very similar between these 6,291 subjects and the other 10,451 subjects examined in NHANES III.

Examinations and laboratory procedures

The documentation for the anthropometry procedures used in NHANES III includes written descriptions and a video demonstration (11,12). Height was measured to the nearest 0.1 cm with a stadiometer, and weight was measured on a Toledo self-zeroing weight scale. Waist circumference was measured at a point that was palpated and marked just above the right ilium (19), and hip circumference was measured at the maximum extension of the buttocks. BAI was calculated as (hip circumference (cm) ÷ height $(m)^{1.5}$) − 18 (1).

Four skinfold thicknesses (subscapular, triceps, suprailiac, and thigh) were measured to the nearest 0.1 mm with a Holtain skinfold caliper, and the sum of these values was used as a simple indicator of body fatness. Although it is known that association between subcutaneous fat and body fatness varies by sex, age, measurement site and across individuals (20), the thickness of various skinfolds is strongly correlated with more accurate estimates of body fatness (13,14).

Methods for determining levels of total cholesterol, triglycerides and lipoprotein cholesterols have been described (21), and these measurements were standardized according to the criteria of the CDC Lipid Standardization Program (22). Levels of LDL-C were estimated using the Friedewald equation (17), plasma glucose by a hexokinase enzymatic reference method (10), and serum insulin by a radioimmunoassay procedure (23). Trained medical professionals measured blood pressures following a standard protocol, and the mid-arm circumference was used to select the appropriate cuff size. Three blood pressure measurements were taken during the household interview and another three were obtained at the mobile examination center. About 8% of the subjects had fewer than 6 blood pressure measurements, with most having three blood pressure measurements. We used the mean of all available (3 or 6) measurements to define levels of SBP and DBP.

One analysis examines the number of adverse CHD risk factors (maximum, 7), based on the following cut points: LDL-C (≥130 mg dL^{-1}), triglycerides (≥150 mg dL^{-1}), HDL-C (<50 mg dL^{-1} among women, <40 mg dL^{-1} among men), fasting glucose (≥100 mg dL^{-1}), SBP (≥130 mm Hg), DBP (≥85 mm Hg), and a fasting insulin ≥ 90th percentile for a subject's sex and age. Although these cut-points are somewhat arbitrary, with the exception of the cut-point for insulin, they have been used in the National Cholesterol Education Program (24) or in the classification of metabolic syndrome (25). Furthermore, the use of other cut-points (e.g., an LDL-C level of 160 mg dL^{-1} or SBP level of 140 mm Hg) yielded similar results. Persons with a LDL-C below 130 mg dL^{-1} who reported taking anti-hyperlipidemic agent (n = 40) were considered to have a high LDL-C level; similarly, 386 persons who had a SBP ≤ 130 mm Hg who reported taking antihypertensive medication were considered to have a high SBP. Medication information was obtained from the prescription medication and drug information files for NHANES III.

Statistical analyses

Because it has been suggested that BAI is a better index of adiposity than BMI (1), the analyses focus on whether skinfold thicknesses and risk factor levels are more strongly correlated with BAI than with BMI. We also examine associations with the waist and hip circumferences to determine if a single circumference can provide information that is comparable to that obtained with BAI. All analyses account for the cluster design and sample weights (for the morning examination) of NHANES III, and were performed using the survey package of R (26,27).

We used principal component analyses to derive an overall summary index of the seven CHD risk factors (LDL-C, HDL-C, triglycerides, insulin, glucose, SBP and DBP) (28). Correlations between the first principal component, which accounted for 30% of the total variability of the seven variables, and levels of the individual risk factors ranged in magnitude from $r = 0.29$ (LDL-C) to $r = 0.63$ (insulin). All factor loadings on the first principal component, which was used as an overall risk summary in the analyses, were >0.30 with the exception of LDL-C (0.20).

To determine if the skinfold thicknesses and risk factor levels were related similarly to BAI and BMI, we examined differences between the weighted correlation coefficients. Unless otherwise noted, these correlations controlled for the effects of sex and age by using the residuals of models in which each characteristic had been regressed on these two covariates. The standard errors of differences between correlation were estimated using jackknife replications with the "with Replicates" function of the R survey package (26). *P* values for these differences were calculated from estimates of the differences and standard errors over the 98 (2 PSUs in 49 strata) replications.

To assess whether BAI provided information on risk factor levels beyond that conveyed by BMI, we examined the proportion of subjects who had adverse levels of three or more CHD risk factors after cross-classifying categories of BMI and BAI. Because the strong association between BMI and BAI resulted in few subjects with extreme combinations of these variables (e.g., a BMI ≥ 35 kg m^{-2} and a low BAI), quartiles of BAI were constructed within each BMI category. Similar analyses were conducted for categories of BMI and waist circumference.

Results

Descriptive characteristics of the sample are shown in Table 1. The median age was 41 years, and 17% (men) to 22% (women) of the survey participants were obese (BMI ≥ 30 kg m^{-2}). There were substantial differences in the anthropometric characteristics between men and women, with women having higher median levels of the skinfold sum (and higher levels of each of the four individual skin-folds) and BAI, but lower levels of BMI, than men. Differences in risk factor levels between men and women did not necessarily parallel differences in BAI or BMI. Despite their higher levels of BAI, women had lower median levels of triglycerides, LDL-C, glucose, SBP and DBP than did men. Overall, 37% of men and 29% of women had adverse levels of three or more CHD risk factors. With the exception of median levels of the hip circumference, total cholesterol and fasting insulin, all sex differences in Table 1 were statistically significant at the 0.001 level.

Correlations between the skinfold sum and the other body size measures are shown for the entire sample and by sex, age group, or race in Table 2. In unadjusted analyses (first row), the skinfold sum was more strongly correlated with BAI ($r = 0.79$) than with BMI ($r = 0.76$) and the other body size measures ($P < 0.001$ for each comparison; H_0, r1 = r2). After adjustment for sex and age (second row), however, the relation of the SF sum to BAI ($r = 0.75$) was significantly weaker than the correlations with BMI, waist circumference, hip circumference and weight ($r = 0.79$ to 0.84; $P < 0.001$ for each comparison with BAI). Analyses stratified by sex confirmed these differences, and fairly similar results were within categories of age and race. With the exception of the unadjusted analyses, both BMI and hip circumference consistently showed stronger associations with the SF sum than did BAI.

We then examined associations with levels of CHD risk factors (Table 3). Among both men and women, the risk factor sum was more strongly associated ($P < 0.01$) with BMI ($r = 0.54$ to 0.56) and waist circumference ($r = 0.54$ to 0.60) than with BAI ($r = 0.42$ to 0.45). Similar differences were seen within the three age categories, as well as for most individual CHD risk factors. For example, among 35- to 49-year-olds, correlations with levels of insulin were $r = 0.59$ (BMI and waist circumference) vs. $r = 0.47$ (BAI), $P < 0.01$ for both differences. None of the CHD risk factors in Table 3 was more strongly associated with BAI than with

BMI. However, several of the weaker associations, such as those with levels of LDL-C, did not significantly differ between BAI, BMI, and waist circumference.

Similar differences between these associations were seen within categories of sex and race-ethnicity (Table 4). For example, the skin-fold sum was more strongly associated with BMI than with BAI in each race-sex group ($P < 0.01$ for each comparison), with the magnitudes of the differences ranging from 0.06 ($r = 0.87$ vs. 0.81, black women) to 0.14 ($r = 0.85$ vs. 0.71, black men). Although associations with the risk factor sum were weaker, this summary measure consistently showed stronger associations with BMI and waist circumference than with BAI in each race-sex group ($P < 0.01$ for each difference).

To assess whether either BAI or waist circumference provided information on risk factor levels that is independent of BMI, we then examined the proportion of subjects who had three or more CHD risk factors after cross-classifying categories of BMI and BAI (Table 5, top) or BMI and waist circumference (Table 5, bottom). Because the strong association between these variables resulted in few subjects in the low/high and high/low categories, quartiles of BAI and waist circumference were constructed within each sex and BMI group.

Despite the observed correlation between BAI and risk factor sum in bivariate analyses, these stratified analyses indicated that BAI provided little information on the presence of multiple CHD risk factors if BMI was known. For example, among men who had a BMI of 30–34.9 kg m^{-2} or ≥35 kg m^{-2}, the prevalence of three or more CHD risk factors was slightly higher among those in the lowest BAI quartile (72 and 88%) than among those in the highest BAI quartile (61 and 80%). Furthermore, it appeared that an independent effect of BAI was limited to persons with a BMI < 25 kg m^{-2}, with the prevalence of multiple CHD risk factors approximately doubling (from about 10–20%) over the 4 BAI categories among both men and women.

In contrast, the effects of waist circumference appeared to be independent of BMI (Table 5, bottom). For example, among men with a BMI of 25–29.9 kg m^{-2}, the prevalence of multiple CHD risk factors increased across waist circumference categories by about threefold among both men (25–62%) and among women (16–59%). Similarly, among persons with a BMI of 30–34.9 kg m^{-2}, the prevalence of multiple CHD risk factors increased from 52 to 73% among men and from 23 to 77% among women.

Discussion

Our results indicate that it is unlikely that BAI is a better index of adiposity among adults than BMI. In contrast to what would be expected if BAI were a better index, after controlling for sex and age, we found the SF sum (triceps, subscapular, suprailiac, and thigh) and levels of CHD risk factors to be more strongly ($P < 0.\ 01$) associated with BMI than with BAI. Furthermore, stratified analyses indicated that BAI provided very little information on risk factor levels if BMI was already known.

These findings agree with those observed among 2,369 18- to 49-year-olds in the Bogalusa Heart Study (29). This previous analysis indicated that (1) BAI is less strongly associated with CHD risk factor levels than is BMI, and (2) dividing the hip circumference by height provided no advantage over using hip circumference alone. The fairly similar associations with the hip circumference and BAI may reflect the weak correlation between body fatness and height that we ($|r| \leq 0.12$, Table 2) and others (30) have observed. It has long been assumed that an optimal index of adult obesity would show little correlation with height (31).

As has been suggested by Schulze and Stefan (32), it is likely that the original derivation of BAI (1) was strongly confounded by sex. This confounding is emphasized by the results of recent studies (2,3) that showed that BMI is as strongly correlated with DXA-calculated percent body fat as is BIA in analyses that controlled for sex through stratification or regression. The results of the current study (Table 2) also show that BIA is more strongly associated with the SF sum than is BMI only when men and women are analyzed together and the confounding effects of sex and age are not controlled.

It was also suggested (1) that BAI can provide an estimate of percent body fat without the need for further adjustment. Subsequent studies, however, have shown that BAI generally overestimates percent body fat among men and underestimates percent body fat women, and that the magnitude of the bias depends upon the level of body fatness (3,33,34). A large underestimation (7%) of percent body fat by BAI has been reported among women (34), and this is likely due to the very high BMI levels of the sample (mean, 35 kg m^{-2}).

A somewhat surprising finding from the 2011 study of Bergman et al. (1) was that DXA-estimated percent body fat was strongly associated with height ($r = -0.52$, Table 2). This inverse association with height, which was based on an analysis of all subjects, led to the decision to standardize hip circumference for height. However, because women are generally shorter and have more body fatness than do men, an analysis that does not control for sex would be expected to overstate (confound) the relation of body fatness to both height and BAI. In the current study, for example, an analysis of men and women together yielded a correlation between height and the skinfold sum of $r = -0.24$ (data not shown) whereas sex-specific correlations were $r = 0.12$ (men) and $r = -0.01$ (women). Furthermore, among 12,957 adults in NHANES 1999–2004, height is strongly correlated ($r = -0.50$) with DXA-calculated percent body fat among all adults, but sex-specific correlations are only $r = -0.02$ (men) and $r = -0.10$ (women) (unpublished observation). It is likely that BAI is a stronger correlate of percent body fat than is BMI only if sex differences in height and body fatness are ignored.

Some investigators have concluded that abdominal obesity, frequently assessed by waist circumference or the waist-to-hip ratio, is more strongly associated with levels of CHD risk factors than is BMI (35), and our results provide support for this possibility. Furthermore, a positive association between the risk factor sum and waist circumference was evident even after controlling for BMI (Table 5). Although it is uncertain if waist circumference is more predictive of CHD and type 2 diabetes than is BMI (7,36), our findings suggest that if a circumference measurement is desired, it is likely that it should be made at the waist rather than at the hip for use in the calculation of BAI. It should also be noted that several studies have found that adults with larger hip circumferences, after adjustment for BMI, have lower

CHD mortality rates (4,37). This further complicates the use of the hip circumference in the numerator of an adiposity index such as BAI.

There are several limitations of the current study. Rather than an analysis of cross-sectional associations, it would be optimal to assess the importance of BAI and BMI in a longitudinal study that focused on disease development. Furthermore, although the current sample is representative of the noninstitutionalized civilian population of the US, it is based on data collected from 1988 to 1994 and fasting, risk factor data were available only for about 40% of the sample. The prevalence of obesity has substantially increased in the US since 1988–1994 (38), and this might have influenced the intercorrelations among BMI, BAI, adiposity and risk factor levels. The hip circumference, however, has not been measured in more recent NHANES, and we found little difference in levels of the body size measures between fasting and non-fasting subjects in NHANES III. In both the current study and the report of Bergman et al. (1), the hip circumference was measured at the maximum extension of the buttocks, and it is possible that this included the anterior abdominal wall of some obese subjects (39).

Another limitation is our use of the sum of four skinfold thicknesses as a surrogate for body fatness. Although skinfold measurements are widely used in epidemiological studies because they are noninvasive and provide a better estimate of adiposity than does BMI, their limitations as measures of body fatness are well known (20,40). Similar differences, however, were observed in the analysis of risk factor levels, with BMI showing stronger associations with the risk factor sum than did BAI following adjustment for sex and age. We are, however, unable to distinguish between characteristics that would be expected to be associated with risk factor levels (e.g., physical activity, nutrition, etc.) and the effects of these characteristics on levels of BMI and BAI.

In summary, we found that among adults who were representative of the US population, both BMI and waist circumference were more strongly correlated with skinfold thicknesses and with levels of CHD risk factors than was the newly proposed BAI. Although these results need confirmation in other data sources, our findings suggest that BAI is not likely to be a better indicator of body fatness or CHD risk than is BMI. If the measurement of weight is difficult, the waist circumference, rather than BAI, should be considered.

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TABLE 1

Median levels of various characteristics among adults in NHANES III (1988–1994)

	Men	Women
N (unweighted)[a]	6,917	7,346
Age (years)	40 ± 0.5[b]	42 ± 0.8
BMI (kg m^{-2})	25.7 ± 0.1 *	24.7 ± 0.1 *
BMI ≥ 30 kg m^{-2} (%)	17% ± 1% *	22% ± 1% *
Waist circumference (cm)	94 ± 0.3 *	86 ± 0.4 *
Hip circumference (cm)	98 ± 0.2	99 ± 0.2
Weight (kg)	79 ± 0.3 *	65 ± 0.3 *
Height (cm)	176 ± 0.2 *	162 ± 0.2 *
Body adiposity index (BAI)[c]	24.3 ± 0.1 *	30.2 ± 0.2 *
Skinfold sum (mm)[d]	66 ± 0.7 *	93 ± 1.3 *
N (unweighted) for risk factors[a]	2,967	3,427
Total cholesterol (mg dL^{-1})	201 ± 1	200 ± 2
Triglycerides (mg dL^{-1})	115 ± 3 *	101 ± 2 *
LDL cholesterol (mg dL^{-1})	130 ± 1 *	121 ± 2 *
HDL cholesterol (mg dL^{-1})	43 ± 0.5 *	53 ± 0.5 *
Insulin (μU mL^{-1})	8.8 ± 0.2	8.3 ± 0.2
Glucose (mg dL^{-1})	96 ± 0.6 *	91 ± 0.8 *
SBP (mm Hg)	122 ± 0.5 *	115 ± 0.6 *
DBP (mm Hg)	76 ± 0.5 *	71 ± 0.5 *
≥3 Risk factors (%)[e]	37% ± 2% *	29% ± 1% *

[a] Two samples were used in the analyses. There are 14,263 subjects with complete data on the body size measures, and 6,291 subjects with complete data on the risk factors.

[b] Values are median (or percent) ± standard error.

[c] Calculated as (hip circumference (cm) ÷ height (m)$^{1.5}$) − 18.

[d] Sum of the triceps, subscapular, SUPrailiac, and thigh skinfolds

[e] The total number of risk factors was 7. The following cut-points were used: LDL-C (≥130 mg dL^{-1} or using lipid-lowering medication), TG (≥150 mg dL^{-1}), HDLC (<50 mg dL^{-1} for women; < 40 mg dL^{-1} for men), glucose (≥ 100 mg dL^{-1}), SBP (≥ 130 mm Hg or using antihypertensive medication), DBP (≥ 85 mm Hg) and an insulin ≥ 90th percentile.

[*] $P < 0.001$ for difference between men and women in median levels or percentages.

TABLE 2

Relation of the skinfold sum to other measures of body size, overall and by sex, age, and race-ethnicity[a]

	Category	BAI	BMI	Waist	Hip	Weight	Height
Overall (unadjusted)[b]	-	0.79	0.76*	0.60*	0.78*	0.52*	−0.24
Overall (adjusted for sex and age)	-	0.75	0.84*	0.81*	0.81*	0.79*	−0.05
Sex	Men	0.70	0.80*	0.81*	0.79*	0.75*	0.12
	Women	0.79	0.86*	0.81	0.82*	0.82*	−0.01
Age (y)	<35	0.78	0.86*	0.84*	0.83*	0.80	0.07
	35–49	0.76	0.84*	0.83*	0.81*	0.80	0.04
	≥50	0.73	0.82*	0.76	0.78*	0.77*	0.03
Race	Whites	0.75	0.83*	0.80*	0.81*	0.79*	0.04
	Blacks	0.80	0.87*	0.84*	0.84*	0.83*	0.04
	Mexican-Americans	0.72	0.82*	0.80*	0.78*	0.78*	0.08

[a] All correlation coefficients are statistically significant at the 0.001 level (H_0: $r = 0$) with the exception of those between height and the skinfold sum (women) and between height and BMI (both men and women). Analyses are based on the 14,263 subjects with nonmissing data the 6 body size measures. The skinfold sum is the sum of the triceps, subscapular, suprailiac, and thigh skinfolds.

[b] With the exception of the first row, all values have been adjusted for sex and age by first regressing levels of the 6 body size measures on these two variables (and their interaction). The correlation coefficients, which accounted for the sample weights, were then calculated using the residuals from these regression models.

* $P < 0.001$ for difference in the correlation with BAI and the specified correlation; the null hypothesis is that the correlation between the skinfold sum with BAI is equal to the correlations between the skinfold sum with BMI, waist, hip, and weight. Among women, for example, the skinfold sum was more strongly associated with BMI ($r = 0.86$) than with BAI ($r = 0.79$), $P < 0.001$.

TABLE 3

Sex- and age-adjusted correlations between BAI, BMI and circumferences and levels of risk factors

		Risk factor sum[a]	Triglycerides	LDL-C	HDL-C	Insulin	Glucose	SBP	DBP
Men (n =2,967)	BAI	0.42	0.22	0.09	−0.21	0.45	0.17	0.15	0.18
	BMI	0.54*	0.29*	0.07	−0.25*	0.57*	0.21*	0.21*	0.25*
	Waist	0.54*	0.31*	0.07	−0.29*	0.56*	0.19	0.20	0.26*
	Hip	0.44	0.20	0.05	−0.23	0.50*	0.15	0.17	0.22
Women (n = 3,324)	BAI	0.45	0.24	0.14	−0.22	0.50	0.19	0.24	0.18
	BMI	0.56*	0.30*	0.17*	−0.29*	0.58*	0.23*	0.28*	0.25*
	Waist	0.60*	0.37*	0.20*	−0.32*	0.50*	0.24*	0.25	027*
	Hip	0.46	0.24	0.12	−0.21	0.50	0.17	0.25	0.24
Age, <35 y (n = 1,978)	BAI	0.47	0.29	0.18	−0.23	0.46	0.22	0.23	0.17
	BMI	0.58*	0.34*	0.18	−0.26*	0.56*	0.24	0.30*	0.25*
	Waist	0.61*	0.39*	0.21	−0.28*	0.56*	0.22	0.29*	0.24*
	Hip	0.50	0.26*	0.14	−0.21	0.50	0.21	0.28	0.24*
Age, 35–49 y (n = 1,617)	BAI	0.49	0.23	0.17	−0.23	0.47	0.17	0.31	0.27
	BMI	0.61*	0.31*	0.17	−0.30*	0.59*	0.22*	0.36*	0.30*
	Waist	0.64*	0.36*	0.18	−0.35*	0.59*	0.26*	0.34	0.36*
	Hip	0.51	0.23	0.13	−0.23	0.50	0.16	0.32	0.32
Age, 50–90 y (n = 2,696)	BAI	0.35	0.18	0.03	−0.18	0.44	0.18	0.14	0.09
	BMI	0.47*	0.26*	0.05	−0.26*	0.54*	0.25*	0.18*	0.17*
	Waist	0.49*	0.29*	0.06	−0.29*	0.54*	0.23*	0.17	0.20*
	Hip	0.36	0.19	0.03	−0.21	0.47	0.17	0.12	0.13

[a]The risk factor sum is the first principal component. Analyses are restricted to subjects with nonmissing levels of the seven risk factors (n = 6,291).

*P < 0.01 for difference between specified correlation and corresponding correlation with BAI. The null hypothesis is that the correlation between the specified risk factor and BAI is equal to the correlation between BMI, waist circumference, or hip circumference and the specified risk factor. Among men, for example, levels of the risk factor sum were more strongly associated with BMI and waist circumference than with BAI (P < 0.01 for both comparisons).

TABLE 4

Stratified (by race and sex) analysis of the relation of BAI, BMI, and circumferences to levels of skinfold sum and risk factor summary

		Whites		Blacks		Mexican Americans	
		Skinfold sum	**Risk factor summary**	**Skinfold sum**	**Risk factor summary**	**Skinfold sum**	**Risk factor summary**
Men	(*N*)	(2,883)	(1,241)	(1,782)	(750)	(2001)	(858)
	BAI	0.71[a]	0.43	0.71	0.42	0.66	0.38
	BMI	0.79*	0.55*	0.85*	0.52*	0.79*	0.52*
	Waist	0.80*	0.56*	0.87*	0.56*	0.81*	0.53*
	Hip	0.79*	0.45	0.84*	0.44	0.75*	0.43
Women	(N)	(3,194)	(1,423)	(2,028)	(926)	(1,814)	(843)
	BAI	0.78	0.45	0.81	0.31	0.75	0.46
	BMI	0.85*	0.58*	0.87*	0.41*	0.84*	0.57*
	Waist	0.80	0.62*	0.82	0.48*	0.79	0.56*
	Hip	0.82*	0.47	0.83*	0.32	0.80*	0.45

[a]Values are sex- and age-adjusted correlation coefficients. Correlations are based on samples sizes of 14,263 (skinfold sum) or 6,291 (risk factor summary); subjects who reported a race-ethnicity other than white, black, or Mexican-American are excluded from this analysis. Skinfold sum is based on 4 (triceps, subscapular, suprailiac, and thigh) skinfold thicknesses.

*$P < 0.01$. *P* values assesses whether the specified correlation is equal to the corresponding correlation with BAI. H_0: the two correlations are equal. Among white men, for example e, levels of BMI, waist circumference, and hip circumference are more strongly associated with the skinfold than is BAI ($P < 0.01$ for each comparison).

TABLE 5

Prevalence of ≥3 risk factors according to categories of BMI, BAI, and waist circumference

Quartiles[a]		BMI ($kg\ m^{-2}$) <25	25–29.9	30–34.9	≥35
BAI					
Men	1	11% (2)[b]	42% (4)	72% (8)	88% (6)
	2	12% (3)	44% (5)	62% (7)	84% (7)
	3	24% (3)	42% (6)	62% (6)	82% (10)
	4	18% (4)	46% (5)	61% (8)	80% (11)
Women	1	9% (2)	36% (4)	56% (7)	63% (7)
	2	14% (2)	32% (4)	55% (6)	60% (6)
	3	15% (3)	37% (5)	41% (7)	68% (10)
	4	18% (3)	30% (4)	58% (7)	66% (6)
Waist circumference					
Men	1	} 7% (2)[c]	25% (6)	52% (9)	86% (8)
	2		38% (5)	66% (6)	61% (12)
	3	17% (3)	49% (6)	64% (5)	91% (6)
	4	33% (4)	62% (4)	73% (7)	90% (8)
Women	1	} 5% (1)[c]	16% (4)	23% (5)	52% (11)
	2		31% (5)	51% (6)	66% (6)
	3	17% (2)	36% (4)	57% (6)	64% (8)
	4	34% (4)	59% (4)	77% (6)	83% (4)

[a] Quartiles of BAI and waist circumference were defined within each sex and BMI category. For example the lowest quartile of BAI among men with a BMI <25 $kg\ m^{-2}$ ranged from 14.1 to 20.7, while the lowest quartile among men with a BMI ≥ 35 $kg\ m^{-2}$ ranged from 19.6 to 30.7.

[b] Values are percent of subjects with ≥3 risk factors (standard error).

[c] Because of the small number of subjects who had multiple risk factors, a BMI < 25 $kg\ m^{-2}$, and a low waist circumference, the lowest two categories of waist circumference were combined in this analysis.